An Improved Hybridizing Biogeography-Based Optimization with Differential Evolution for Global Numerical Optimization

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Abstract. Biogeography-based optimization (BBO) is a new biogeography inspired algorithm. It mainly uses the biogeography-based migration operator to share the information among solution. Differential evolution (DE) is a fast and robust evolutionary algorithm for global optimization. In this paper, we applied an improved hybridization of BBO with DE approach, namely BBO/DE/GEN, for the global numerical optimization problems. BBO/DE/GEN combines the exploitation of BBO with the exploration of DE effectively and the migration operators of BBO were modified based on number of iteration to improve performance. And hence it can generate the promising candidate solutions. To verify the performance of our proposed BBO/DE/GEN, 6 benchmark functions with a wide range of dimensions and diverse complexities are employed. Experimental results indicate that our approach is effective and efficient. Compared with BBO and BBO/DE approaches, BBO/DE/GEN performs better, or at least comparably, in terms of the quality of the final solutions and the convergence rate.

Introduction

Biogeography-based optimization (BBO) algorithm (Simon, 2008) is based on the mechanism of the species migrating from one island to another in nature. Based on two main operators, migration and mutation, BBO is of good exploitation ability, but it is weak in exploration search. As another comparatively new evolutionary algorithm, differential evolution (DE) is good at exploring global searching space with three control parameters. In order to enhance the exploration ability of BBO, we hybridize the exploitation of BBO with the exploration of DE to design a hybrid algorithm named BBO/DE for global numerical optimization problems.

In this paper, we proposed an improved hybrid BBO/DE algorithm, which incorporates the mutation procedure inherited from DE to replace the BBO-based mutation, for global numerical optimization problems. And a new migration operator is proposed based on number of iteration to improve performance. Especially, the migration and mutation mechanism are combine so that the exploration and exploitation abilities are enhanced. Experiments have been tested on 6 benchmark functions, which demonstrate the validity and effectiveness of the proposed improved hybrid algorithm.

The remainder of the paper is organized as follows. Function optimization problem and related implementation technology are described in Section 2. The hybrid algorithm for global numerical optimization problems is proposed in Section 3. Comparisons with some existing approaches are provided in Section 4. Finally, we draw the conclusions in Section 5.

Preliminary

2.1 Problem definition

Global numerical optimization problems are frequently arisen in almost every field of engineering design, applied sciences, molecular biology and other scientific applications. In global numerical optimization problems, the major challenge is that an algorithm may be trapped in the local optima of the objective function. This issue is particularly challenging when the dimension is high. In this work, we only consider the unconstrained function optimization.

2.2 Differential evolution

Differential evolution [1] is a simple EA that creates new candidate solutions by combining the parent individual and several other individuals of the same population. A candidate replaces the parent only if it has better fitness. DE's advantages are its simple structure, ease of use, speed and robustness. Due to these advantages, it has been applied to many real world applications, such as data mining, pattern recognition, digital filter design, neural network training, etc. Most recently, DE has also been used for optimal power problem [2].

2.3 Biogeography-based optimization

The biogeography-based optimization algorithm proposed by Simon is a new nature-inspired computation technique based on the mathematical models of biogeography to find the optimal solution of the problem [3]. The solution process is analogous to the migration of the species in nature. The BBO algorithm operates on a population of individuals called habitats (or islands). Each habitat represents a possible solution to the problem in hand. The fitness of each habitat is determined by its habitat suitability index (HSI). High HSI solutions are more likely to share their features with other solutions, and low HSI solutions are more likely to accept shared features from other solutions. The sharing of features between solutions is represented as immigration and emigration between the islands [4].

BBO/DE/GEN for global numerical optimization problems

As mentioned above, BBO has a good exploitation for global optimization [3]. However, it is slow exploring of the search space. On the other hand, DE is good at exploring the search space and locating the region of global minimum. Based on these considerations, in order to balance the exploration and the exploitation of BBO, in this work, we propose a hybrid BBO approach, called BBO/DE/GEN, which combines the exploitation of BBO with the exploration of DE effectively. And a new migration operator is proposed based on number of iteration to improve performance.

3.1 Mutation operator for global numerical optimization problems

In BBO, if a solution is selected for mutation, then it is replaced by a randomly generated new solution set. This random mutation affects the exploration ability of BBO. In BBO/DE/GEN, modified mutation operator creates new feasible solution by inheriting from DE to replace the BBO-based mutation. A mutated individual SIV ($H_{i(j)}$) is generated according to the following equation

$$H_i(j) = H_i(j) + F*(H_{best}(j) - H_i(j)) + F*(H_{r1}(j) - H_{r2}(j)) \quad (1)$$

Where $H_{i(j)}$ is the parent SIV to be mutated, F is the mutation scaling factor. $H_{r1(j)}, H_{r2(j)}$ is the randomly selected SIV ($r \in [1, popsize]$). In BBO/DE/GEN, This mutation scheme tends to increase the diversity among the population.

3.2 Migration operator

In BBO, there are two main operators: migration and mutation. Modified migration operator is a generalization of the standard BBO migration operator and which is motivated from [5]. Modified migration is defined as

$$H_i(s) = \frac{t}{t_{\max}} H_i(s) + (1 - \frac{t}{t_{\max}}) H_j(s) \quad (2)$$

Where H_i is the ith candidate solution in the BBO population, s is its solution feature, and t is number of iteration, $t_{\max}$ is maximum number of iteration. Equation (2) means that a solution feature of solution H_i is comprised of two components: the migration of a feature from another solution, and the migration of a feature from itself.

3.3 Main procedure of improved BBO/DE for global numerical optimization

By incorporating the above-mentioned migration operator and mutation operator into BBO, the BBO/DE/GEN approach is developed and shown in Algorithm 1. BBO/DE/GEN is able to explore the new search space with the mutation operator of DE and to exploit the population information with the migration operator of BBO. This feature overcomes the lack of exploration of the original BBO algorithm. Note that the only difference between BBO/DE/GEN and the original BBO algorithm is that DE is used to replace the original BBO mutation operator and improved migration operator of BBO. Our proposed BBO/DE/GEN approach is described as follows.

Algorithm 1: The main procedure of BBO /DE/GEN for global numerical optimization

1. Generate the initial population P. Modification probability, mutation probability, elitism parameter, number of iterations
2. Evaluating the fitness function for each individual in P.
3. While the halting criterion is not satisfied do
4. For each individual, map the fitness to the number of species
5. Calculate the immigration rate λ_i and the emigration rate μ_i for each individual x_i
6. Modify the population with the migration operator shown in Eq. (1)
7. Modify the population with the mutation operator Shown in Eq. (2)
8. Evaluating the fitness function
9. Sort the population from best to worst
10. Replace the worst with the previous generation's elites.
11. Clear any duplicates by randomly population mutation.
12. End while

Experiments

In order to verity the performance of BBO/DE/GEN, 6 benchmark functions are briefly described as follows. Functions f05 is unimodal, functions f09–f13 are multimodal functions where the number of local minima increases exponentially with the problem dimension. They appear to be the most difficult class of problems for many optimization algorithms. Moreover, in our experiments, each function is optimized over 50 independent runs. DE mutation scheme is DE/rand/1/bin, population size is 50, generation count is 50, number of variables in each population is 20, mutation probability is 0.05, elitism parameter is 10, Habitat modification probability is 1, and scaling factor is 0.5.

In order to show the superiority of our proposed BBO/DE/GEN approach, we compare it with the BBO/DE algorithm and the BBO algorithm. Minimum cost and Average cost graphs of BBO/DE/GEN, BBO/DE, and BBO for 6 benchmark functions are respectively shown in figure 1 to figure 6.

From figure 1 to figure 6, it is obvious that BBO/DE/GEN performs significantly better than BBO/DE and BBO for 6 typical benchmark functions.

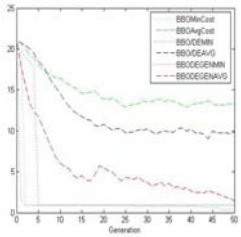

Fig.1. Ackley's function.

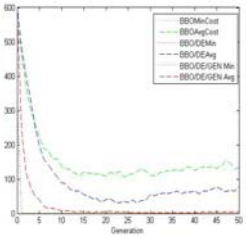

Fig. 2. Griewank function.

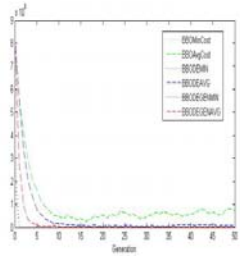

Fig.3. Penalized function 1.

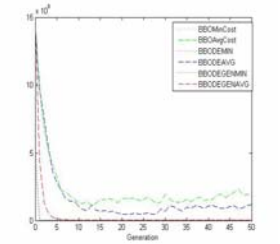

Fig.4. Penalized function 2.

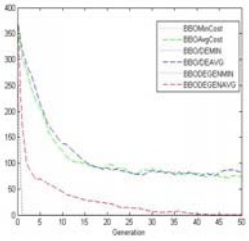

Fig.5. Rastrigin's function.

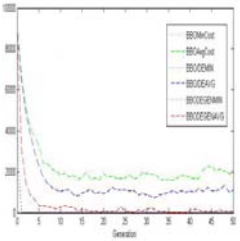

Fig.6. Rosenbrock's function.

Conclusion

In order to balance the exploration and the exploitation of BBO, in this paper, we propose a hybrid BBO approach for the global numerical optimization problems, called BBO/DE/GEN, which combines the exploitation of BBO with the exploration of DE. And a new migration operator is proposed based on number of iteration to improve performance. Since the hybrid mutation operator has a good trade-off between the exploration and the exploitation, it makes our proposed BBO/DE/GEN approach be very effective and efficient. To verify the performance of BBO/DE/GEN, 6 typical benchmark functions chosen from literature are employed. Compared with BBO, BBO/DE, experimental results show that BBO/DE/GEN is superior to or at least highly competitive with them. It demonstrates the good performance of our approach.

Acknowledgment

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